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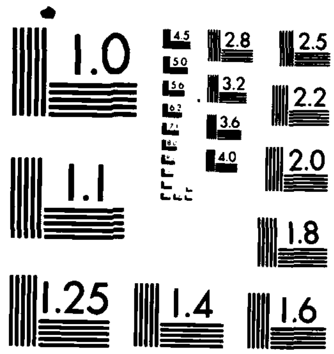

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AD-A162 189

GPIB Interface and Timing Generator for the Hewlett-Packard 2401C Integrating Digital Voltmeter

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30 September 1985

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

GPIB interface logic and a timing generator for the Hewlett-Packard 2401C integrating digital voltmeter were designed, constructed, and checked out. This logic enables the control of the 2401C by a Hewlett Packard 9825T calculator. This hardware is described herein. Also described is software for a typical usage for the voltmeter, calculator, and interface system with a printer and plotter as outputting devices.

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CONTENTS

A-1

FIGURES

TABLES

I. INTRODUCTION

The GPIB interface and timing generator for the Hewlett Packard (or DYMEC) 2401C allow calculator control of the integration time of the 2401C and also enable the calculator to read the 2401C output.

The block diagram (Fig. 1) shows the functional elements of the "GPIB/TIMING GENERATOR INTERFACE." The GPIB (IEE 488) protocol is handled by a 74LS488 integrated circuit along with a few support integrated circuits. A 10 MHz crystal clock required for operation of the 74LS488 is divided by 10^5 to produce a 10 ms clock for the timing generator. This clock is used for counting down a four-digit presettable counter. The timing generator provides the start/stop information for the 2401C. The timing range is 0.01 to 99.99 sec in steps of 10 ms. We should note that the time between integration times (i.e., the "dead time") is a minimum of about 17 ms for the circuit implementation described in this report. The problem of integration time selection to achieve rejection of 60 Hz and harmonic components is discussed in Appendix A. The quantization level of the 2401C and how it is set are discussed in Appendix B.

Output data from the 2401C is formatted as eight binary-coded decimal (BCD) words of six digits plus sign and exponent. These data are parallel loaded into four 8 bit shift registers. The data are then outputted sequentially over the GPIB as eight data words. The circuit details of the unit are given in Figs. 2 through 4. In Table 1 are listed the interconnections for the 2401C and GPIB interface logic.

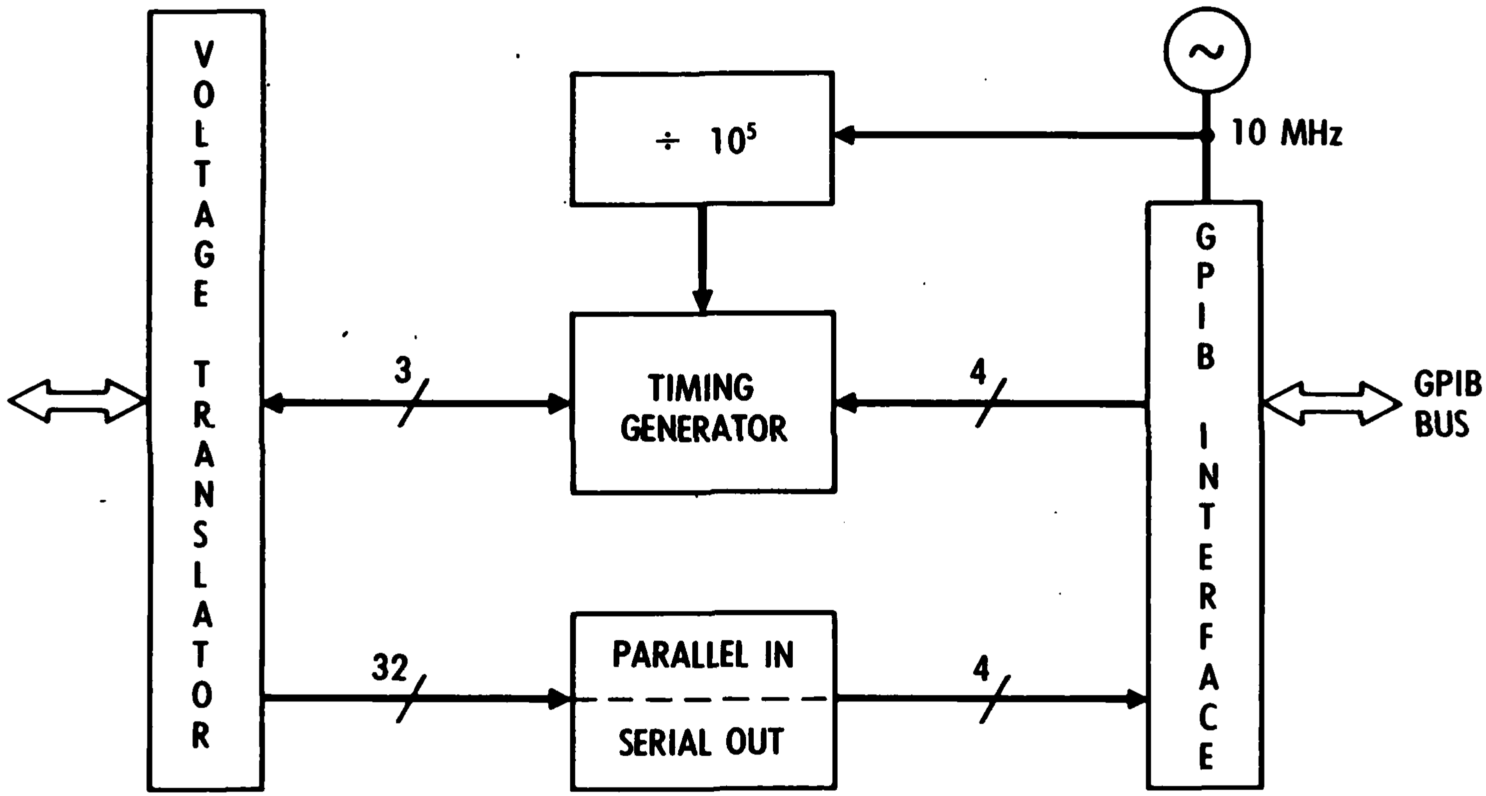


Fig. 1. Functional Block Diagram

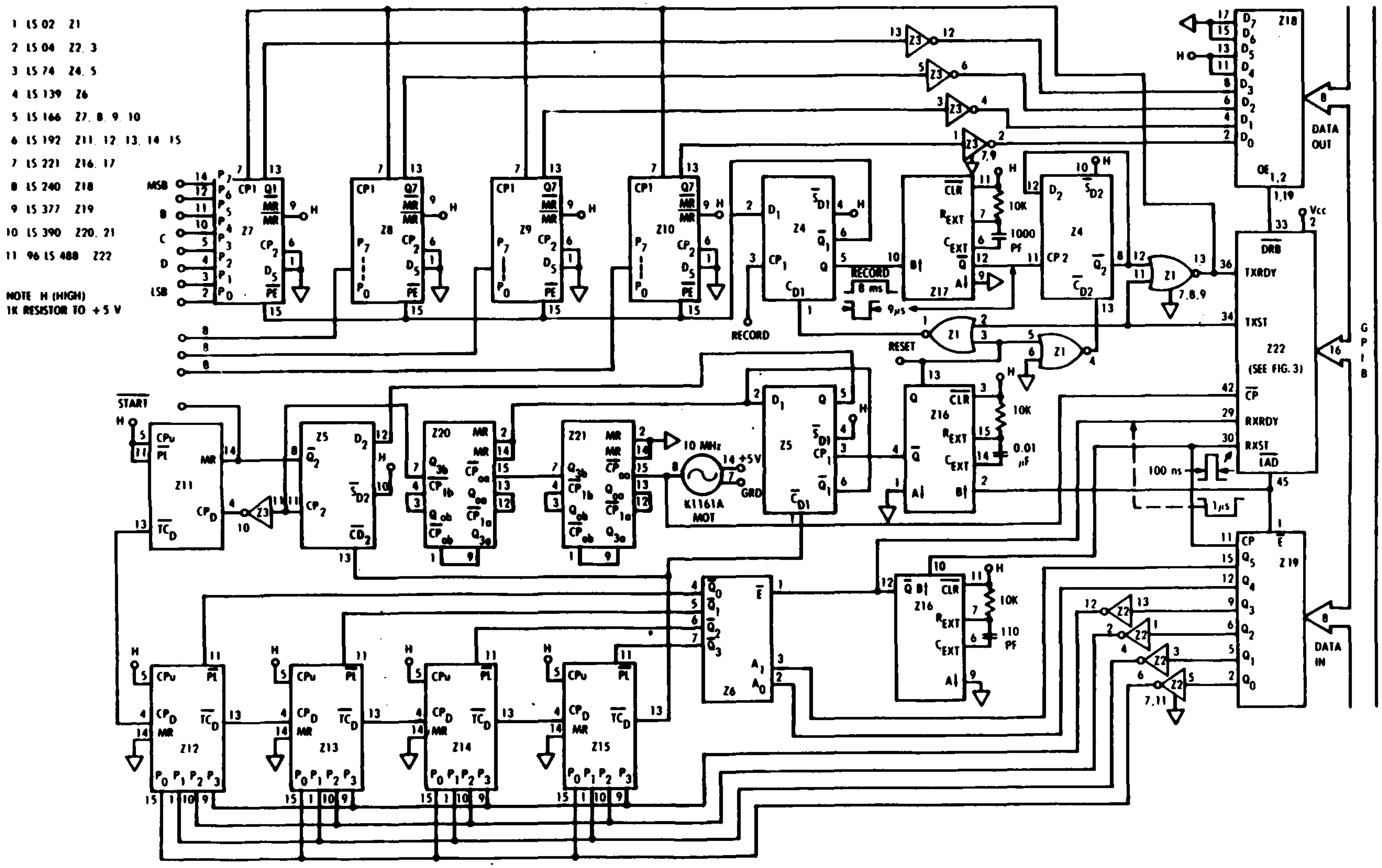
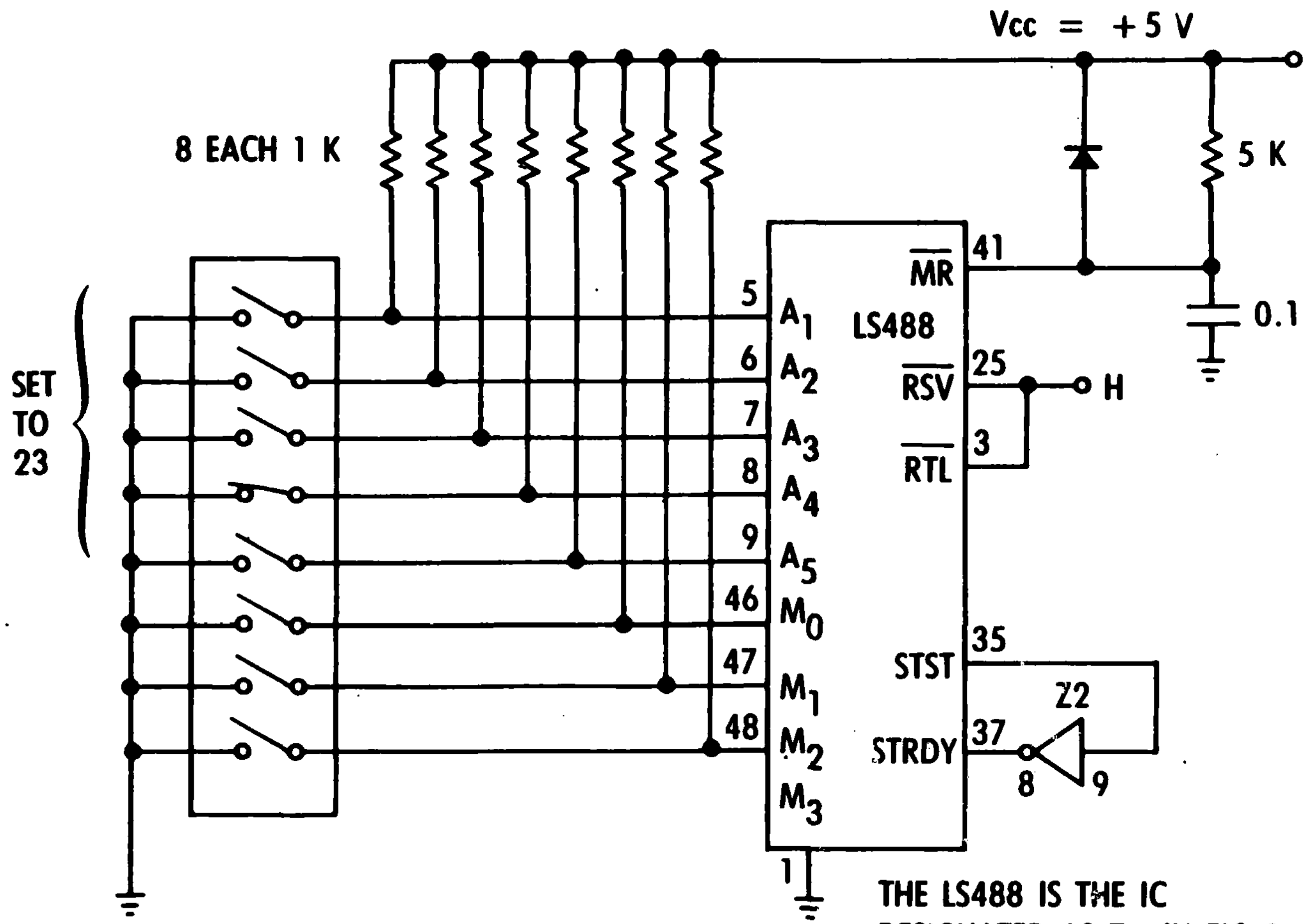


Fig. 2. GPIB Interface Logic for 2401C (IDVM)



THE LS488 IS THE IC DESIGNATED AS Z_{22} IN FIG. 2

Fig. 3. Address and Mode Select GPIB Interface Circuit

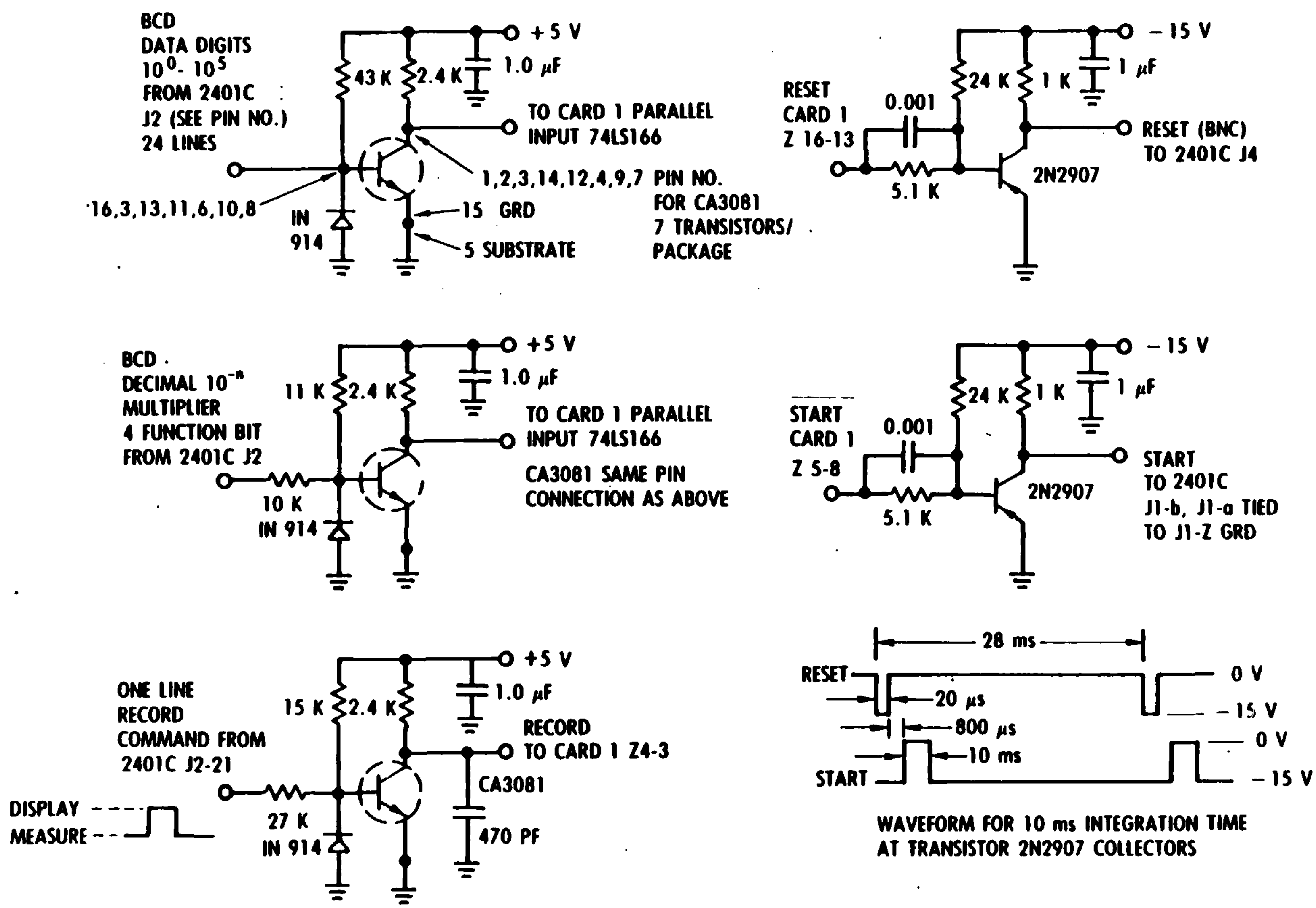


Fig. 4. GPIB Interface Drivers, Card 2

Table 1. Interconnections for 2401C and GPIB Interface Logic

2401C Connector J2 Pin No.	BCD Weight and Coding of Outputs from 2401C[a]	3M Connector 3429-4005 26 Pins (2 each)	CA3081 Base Card 2	CA3081 Collector Card 2	On-Board Terminal	Shift Register 74LS166 Card 1
1	10^{-n} 1	1	Z4-11	Z4-12	1	Z10-2
2	10^{-n} 2	14	Z4-6	Z4-4	2	Z9-2
3	10^{0} 1	2	Z1-16	Z1-1	3	Z10-3
4	10^{0} 2	15	Z1-3	Z1-2	4	Z9-3
5	10^{1} 1	3	Z1-6	Z1-4	5	Z10-4
6	10^{1} 2	16	Z1-10	Z1-9	6	Z9-4
7	10^{2} 1	4	Z2-3	Z2-2	7	Z10-5
8	10^{2} 2	17	Z2-13	Z2-14	8	Z9-5
9	10^{3} 1	5	Z2-10	Z2-9	9	Z10-10
10	10^{3} 2	18	Z2-8	Z2-7	10	Z9-10
11	10^{4} 1	6	Z3-13	Z3-14	11	Z10-11
12	10^{4} 2	19	Z3-11	Z3-12	12	Z9-11
13	10^{5} 1	7	Z3-8	Z3-7	13	Z10-12
14	10^{5} 2	20	Z4-16	Z4-1	14	Z9-12
15	Function 1	8	Z5-16	Z5-1	15	Z10-14
16	Function 2	21	Z5-3	Z5-2	16	Z9-14
17					Record Pin 17	
18					Reset 18	
19					+ 5 19	
20					$\overline{\text{Start}}$ 37	Z5-8
21					Ground 20	
22						
23						

Table 1. Interconnections for 2401C and GPIB Interface Logic (Continued)

2401C Connector J2 Pin No.	BCD Weight and Coding of Outputs from 2401C[a]		3M Connector 3429-4005 26 Pins (2 each)	CA3081 Base Card 2	CA3081 Collector Card 2	On-Board Terminal	Shift Register 74LS166 Card 1
24							
25							
26	10^{-n}	4	1	Z4-10	Z4-9	21	Z8-2
27	10^{-n}	8	14	Z4-8	Z4-7	22	Z7-2
28	10^0	4	2	Z1-13	Z1-14	23	Z8-3
29	10^0	8	15	Z1-11	Z1-12	24	Z7-3
30	10^1	4	3	Z1-8	Z1-7	25	Z8-4
31	10^1	8	16	Z2-16	Z2-1	26	Z7-4
32	10^2	4	4	Z2-11	Z2-1	27	Z8-5
33	10^2	8	17	Z2-6	Z2-4	28	Z7-5
34	10^3	4	5	Z3-16	Z3-1	29	Z8-10
35	10^3	8	18	Z3-3	Z3-2	30	Z7-10
36	10^4	4	6	Z3-6	Z3-4	31	Z8-11
37	10^4	8	19	Z3-10	Z3-9	32	Z7-11
38	10^5	4	7	Z4-3	Z4-2	33	Z8-12
39	10^5	8	20	Z4-13	Z4-14	34	Z7-12
40	Function	4	8	Z5-13	Z5-14	35	Z8-14
41	Function	8	21	Z5-11	Z5-12	36	Z7-14
⋮							
50	Ground		25				

[a]Listing is for a 1248 code (option M21). Other options use a 122'4 code.

II. EXAMPLE OF A TYPICAL USAGE

A typical data acquisition test setup is shown in Fig. 5. Following Fig. 5 is Table 2, which is a listing of a data acquisition and reduction program used with the test setup. Following the program are instructions for using the program (Section III), the 2401C control settings and connections (Section IV), and lastly a program flow chart, depicted as Fig. 6.

To illustrate the use of the program, the noise output of a LM194 op-amp set for a voltage gain of 50 and with a 2000 ohm termination was used as an input to the 2401C. Table 3 and Fig. 7 give the results for a manual mode run for 50, 1-sec integration data points. The output for a typical automatic mode sequence is shown in Table 4. The sequence is for 50 integration times of 1 and 2 sec, three blocks of each, and two iterations.

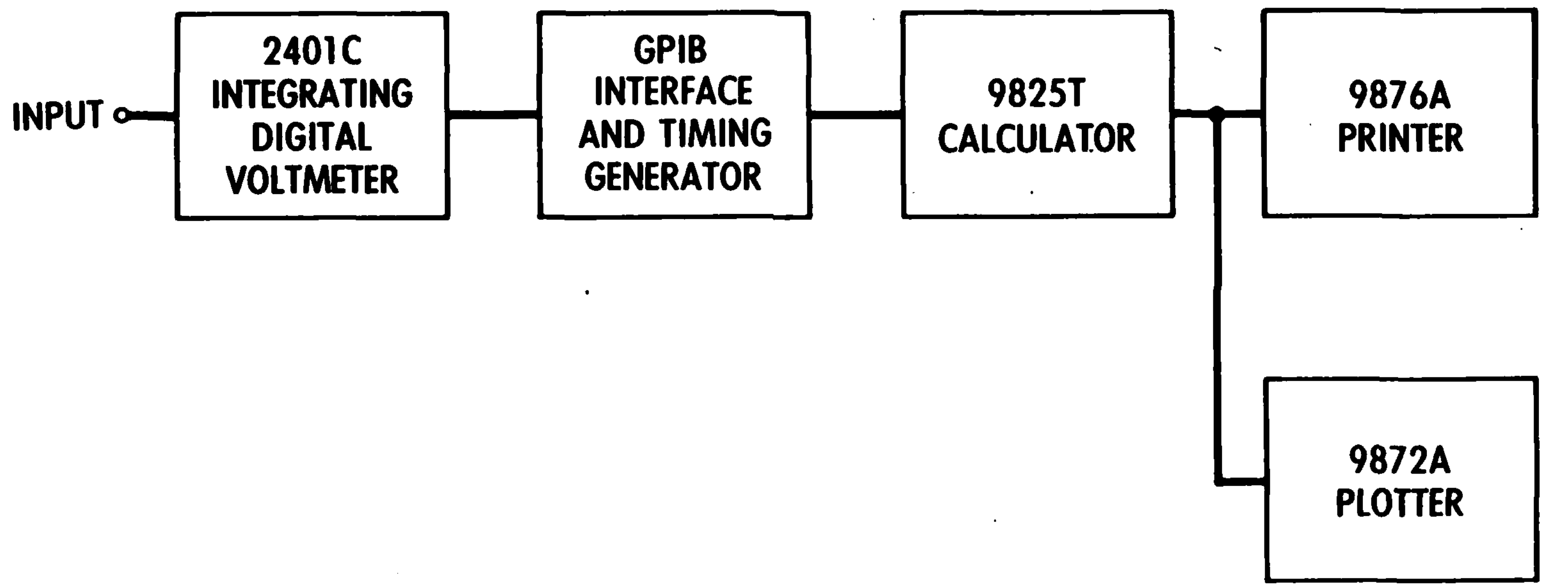


Fig. 5. Data Acquisition Block Diagram

Table 2. Data Acquisition and Reduction Program

```
0:    "IDVM Ver 2.0 (MFB 831012 [12/16/83])":
1:    "For use with 2401C interface Don-1":
2:    "added avg std dev & avg dev\T 2/22/84":
3:    dim D[4],D$[8],P$[10],L$[80],T[22],X$[80],T$[20]
4:    dev "M",723,"P",701;fmt 8,c,z
5:
6:    ent "1 2 2' 4 code (Y)?",P$
7:    if cap(P$)="Y";sfg 8
8:    ent "AUTO MODE (Y)?",P$
9:    if cap(P$)="Y";sfg 2
10:
11:   "Bgn":cll 'Time';wrt "P","IDVM Ver 2.0 "&T$
12:   1)T)T[1];ent "Label",L$
13:   if flg13;X$)L$
14:   L$)X$;wrt "P",L$
15:   ent "NUMBER OF SAMPLES ?",N;int(N))N
16:   if N<=1;jmp -1
17:   if flg2;gto "Setup"
18:   ent "SAMPLE INTEGRATION TIME [Sec]?",T[1]
19:   if T[1]>99.99 or T[1]<.01;jmp -1
20:
21:   "Loop":if flg2;gsb "GEN"
22:   0)P)0)X)Y;fxd 0;sfg 1
23:   if flg8;conv 54,52,55,53,60,54,61,55,62,56,63,57
24:   10000+int(.5+100T[T]))D
25:   str(D))D$;D$[3])D$
26:   for I=1 to 4;48+161+val(D$[I,I])D[I];next I
27:
28:   for I=1 to N;dsp I
29:   wtb "M",D[4],D[3],D[2],D[1]
30:   red "M.8",D$
31:   val(D$[2,7]))V
32:   V/tn^val(D$[8,8]))V
33:   if D$[1,1]="2";-V)V
34:   V)rI;next I
35:
36:   r1/T[T])H)L
37:   for I=1 to N;rI/T[T))V)rI
38:   if V>H;V)H
39:   if V<L;V)L
40:   I+X)X;V+Y)Y
41:   IV+P)P;II+Q)Q
42:   next I
43:   (NP-XY)/(NQ-XX))A
44:   (YQ-XP)/(NQ-XX))B
45:   Y/N)M;0)P)Y; for I=1 to N
```

Table 2. Data Acquisition and Reduction Program (Continued)

```
rI-AI-B)V;V+Y)Y;VV+P)P
next I
(NP-YY)/N(N-1))V;\V)S
conv;if flg2;gto "LIST"
"Out":beep;ent "PLOT/LIST/NEXT (P/L/N) ?",P$
if flg13;gto +4
if cap(P$[1])="P";gto "PLOT"
if cap(P$[1]="L";gto "LIST"
if cap(P$[1])="N";gto "Bgn"
prt "No. of Pts.="&str(N)
fxd 6;prt "Mean=",M
prt "Std Dv=",S
prt "Slope=",A
prt "Y Int=",B
gto "Bgn"
"PLOT":pclr;scl 0,N,M-1.5(M-L),M+1.5(H-M)
pen# 3;fxd 0;xax M,1,0,N,5
fxd int(.5-log((H-L)/10))E;yax 0,tn^(-E),L,H,2
pen# 2;plt 1,rI,-2
for I=1 to N;plt I,rI;next I
scl 0,10,0,10
plt 2,10,1
pen# 1;lbl L$
pen# ;gto "Out"
"LIST":wrt "P"
cll 'Time';wrt "P",T$
if W=1;gto "L"
fmt 1,f12.7,z
fmt 2,f12.7
for I=1 to 1+int(N/6)
for J=1 to 6
6<I-1>+J)K
if K>N;gto "L"
if K=N or J=6;wrt "P.2",rK;gto +2
wrt "P.1",rk
next J
next I
"L":fmt 1,c18,f11.8;fxd 0;wrt "P"
wrt "P","  No. of Points="&str(N)
wrt "P.1","Integ. Time=",T[T]
wrt "P.1","Mean=",M
wrt "P.1","Std. Deviation=",S
```

Table 2. Data Acquisition and Reduction Program (Continued)

```
92:  wrt "P.1","Slope=",A
93:  wrt "P.1","Y Intercept=",B
94:  wrt "P";if flg2;gto "Loop"
95:  gto "Out"
96:
97:  "Setup":1)I;0)G)S)T)Z;fxd 0
98:  for J=1 to 22;0)T[J];next J
99:  str(I))P$;dsp "SAMPLE INTEGRATION TIME: T["&P$[2]&"]=?"
100: ent "",T[I]
101: if T[I]>99.99;jmp -2
102: if I<19 and not flg13;I+1)I;gto -3
103: ent "NUMBER OF BLOCKS OF SAMPLES?", T[20]
104: ent "NUMBER OF ITERATIONS?",T[21]
105: ent "DATA POINTS LISTED (N)?",P$
106: cap(P$)="N")W
107" gto "Loop"
108:
109: "GEN":G+1)G;if G>T[20];1)G
110: SS+Z)Z
111: if G#1;ret
112: if Z=0;gto +4
113: wrt "P.1","Avg std dev=",\(Z/T[20]))Z
114: wrt "P.1","std dev \ T=",Z\T[T]
115: 0)S)Z
116: T+1)T;if T[T]=0;1)T;T[22]+1)T[22]
117: if T[22]<T[21];ret
118: gto "Bgn"
119:
120: "Time":wrt 8,"R"
121: red 8,T$
122: T$[7])P$
123: "/")T$[3,3])T$[6,6];"84")T$[7,8]
124: P$&" "&T$[1,8])T$;ret
*4134
```

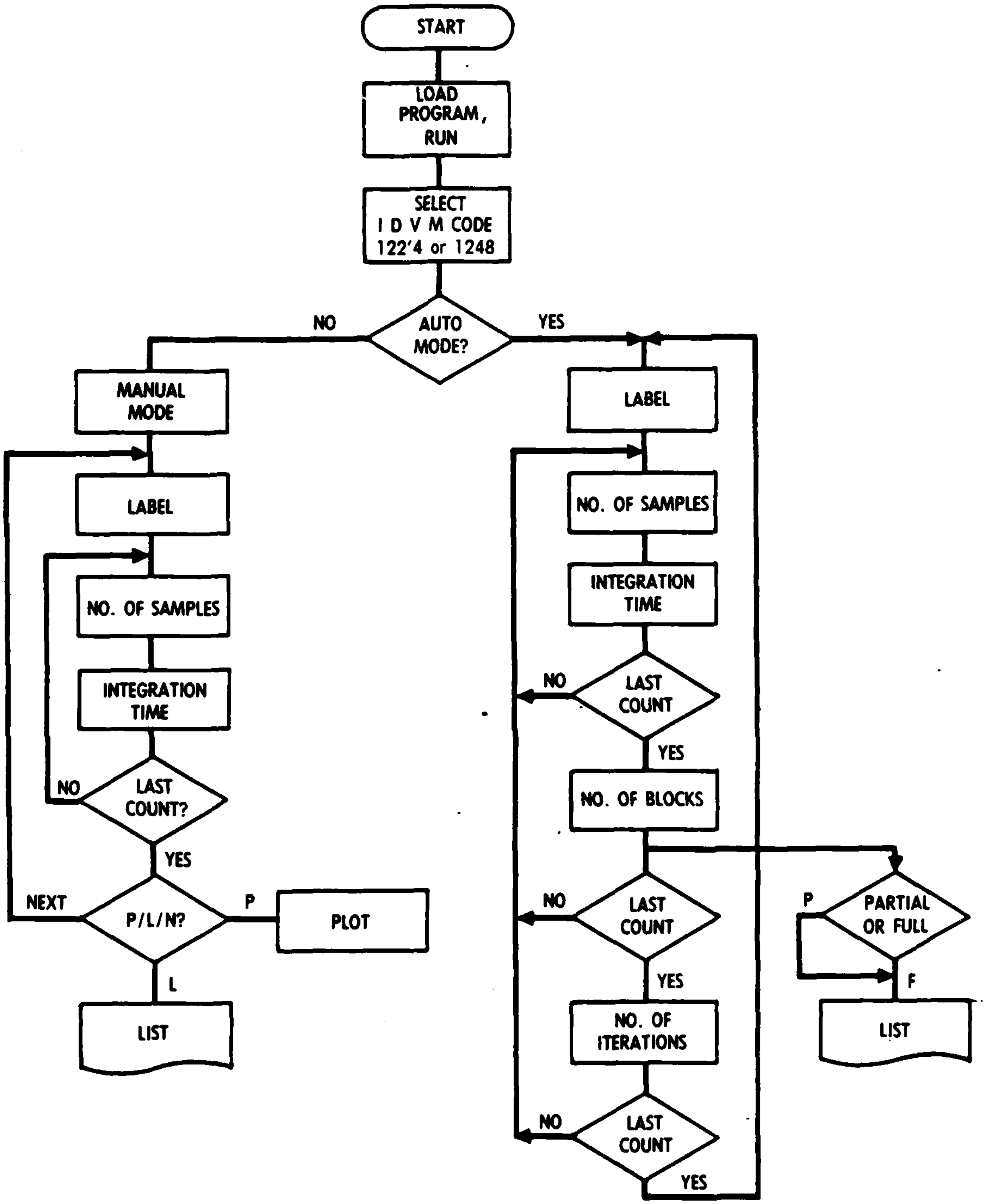


Fig. 6. Data Acquisition Flow Chart Using 9825T Calculator and 2401C IDVM

Table 3. Manual Mode Output

```
IDVM Ver 2.0  13:20:30 04/18/84
Noise meas. LM194 G=50 input term. 2k

13:23:48 04/18/84
   -0.0284150 -0.0284150  -0.0284470  -0.0284260  -0.0284360  -0.0284100
   -0.0283810 -0.0283860  -0.0283820  -0.0283860  -0.0283780  -0.0283610
   -0.0283660 -0.0283520  -0.0283580  -0.0283810  -0.0284030  -0.0284130
   -0.0284140 -0.0284250  -0.0284210  -0.0284090  -0.0284070  -0.0284170
   -0.0284570 -0.0284530  -0.0284330  -0.0284420  -0.0284650  -0.0284760
   -0.0284910 -0.0285020  -0.0284950  -0.0284710  -0.0284280  -0.0284080
   -0.0284280 -0.0284430  -0.0284400  -0.0284630  -0.0284390  -0.0284450
   -0.0284530 -0.0284460  -0.0284500  -0.0284650  -0.0284700  -0.0284680
   -0.0284830 -0.0285100

 No. of Points= 50  .
   Integ. Time= 1.00000000
          Mean=-0.02843026
Std. Deviation= 0.00002863
         Slope=-0.00000180
   Y Intercept=-0.02838436
```

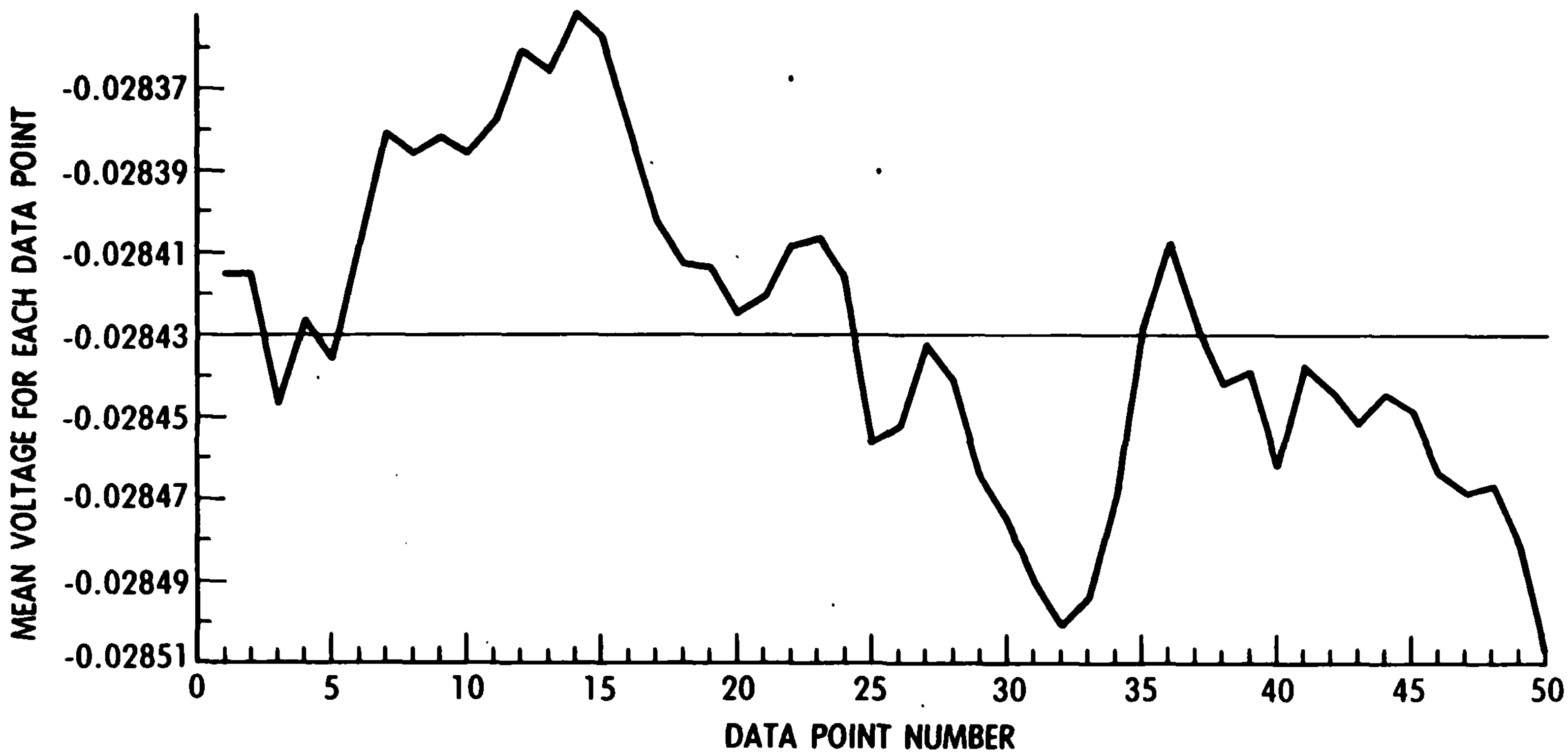


Fig. 7. Plot of Table 3 Data Set

Table 4. Automatic Mode Output

IDVM Ver 2.0 13:53:45 04/18/84
noise meas. LM194 G=50 input term 2k

13:57:20 04/18/84

-0.0277580	-0.0277910	-0.0277790	-0.0277930	-0.0277530	-0.0277630
-0.0277700	-0.0277560	-0.0277540	-0.0277320	-0.0277090	-0.0277300
-0.0277310	-0.0277130	-0.0277310	-0.0277440	-0.0277570	-0.0277380
-0.0277420	-0.0277300	-0.0277700	-0.0277710	-0.0277900	-0.0277880
-0.0277980	-0.0277760	-0.0277630	-0.0277380	-0.0277490	-0.0277790
-0.0277990	-0.0277870	-0.0277590	-0.0277620	-0.0277690	-0.0277810
-0.0278140	-0.0277970	-0.0277790	-0.0278040	-0.0278020	-0.0277850
-0.0277900	-0.0278000	-0.0277960	-0.0278030	-0.0278110	-0.0278170
-0.0278140	-0.0277920				

No. of Points= 50
Integ. Time= 1.00000000
Mean=-0.02777114
Std. Deviation= 0.00002185
Slope=-0.00000120
Y Intercept=-0.02774059

13.58:14 04/18/84

-0.0278050	-0.0277820	-0.0277710	-0.0277650	-0.0277630	-0.0278000
-0.0278040	-0.0278070	-0.0278060	-0.0277970	-0.0278200	-0.0278140
-0.0277790	-0.0277660	-0.0277910	-0.0278040	-0.0278250	-0.0278130
-0.0278110	-0.0277970	-0.0278230	-0.0278610	-0.0278770	-0.0278630
-0.0278800	-0.0278740	-0.0278620	-0.0278470	-0.0278400	-0.0278310
-0.0277890	-0.0277720	-0.0277830	-0.0277840	-0.0277580	-0.0277640
-0.0277580	-0.0277830	-0.0277980	-0.0277930	-0.0277960	-0.0277760
-0.0277650	-0.0277650	-0.0277450	-0.0277650	-0.0277670	-0.0277440
-0.0277370	-0.0277360				

No. of Points= 50
Integ. Time= 1.00000000
Mean=-0.02779712
Std. Deviation= 0.00003508
Slope= 0.00000083
Y Intercept=-0.02781835

Table 4. Automatic Mode Output (Continued)

13:59:09 04/18/84

-0.0277200	-0.0277210	-0.0277020	-0.0276900	-0.0277180	-0.0277120
-0.0276900	-0.0276960	-0.0277090	-0.0277010	-0.0277020	-0.0277110
-0.0277120	-0.0276920	-0.0277000	-0.0277120	-0.0277260	-0.0277300
-0.0277330	-0.0277040	-0.0276890	-0.0276960	-0.0276880	-0.0277300
-0.0277170	-0.0277150	-0.0277250	-0.0277430	-0.0277500	-0.0277600
-0.0277420	-0.0277550	-0.0277430	-0.0277460	-0.0277440	-0.0277250
-0.0277270	-0.0277610	-0.0277570	-0.0277630	-0.0277430	-0.0277570
-0.0277250	-0.0277220	-0.0277370	-0.0277170	-0.0277060	-0.0276870
-0.0277150	-0.0277060				

No. of Points= 50
Integ. Time= 1.00000000
Mean=-0.02772144
Std. Deviation= 0.00001960
Slope=-0.00000066
Y Intercept=-0.02770460

Avg std dev= 0.00002641
std dev \ T= 0.00002641

14:00:53 04/18/84

-0.0276815	-0.0277020	-0.0277145	-0.0276870	-0.0277030	-0.0276930
-0.0276990	-0.0276830	-0.0276545	-0.0276370	-0.0276160	-0.0276735
-0.0276430	-0.0276385	-0.0276150	-0.0276045	-0.0275730	-0.0276010
-0.0275920	-0.0276230	-0.0276135	-0.0276135	-0.0276115	-0.0276320
-0.0276100	-0.0276210	-0.0276120	-0.0276130	-0.0276215	-0.0276045
-0.0276260	-0.0276410	-0.0276455	-0.0276620	-0.0276590	-0.0276485
-0.0276880	-0.0276970	-0.0276835	-0.0277220	-0.0277535	-0.0277580
-0.0277705	-0.0277730	-0.0277495	-0.0277220	-0.0277340	-0.0277630
-0.0277400	-0.0277080				

No. of Points= 50
Integ. Time= 2.00000000
Mean=-0.02766661
Std. Deviation= 0.00004873
Slope=-0.00000161
Y Intercept=-0.02762565

Table 4. Automatic Mode Output (Continued)

14:02:38 04/18/84

-0.0276540	-0.0276790	-0.0276845	-0.0277025	-0.0276745	-0.0276795
-0.0276665	-0.0276665	-0.0276500	-0.0276640	-0.0276545	-0.0276675
-0.0276890	-0.0276810	-0.0276770	-0.0276520	-0.0276515	-0.0276280
-0.0275985	-0.0275895	-0.0275960	-0.0275860	-0.0275975	-0.0275810
-0.0275980	-0.0275675	-0.0275620	-0.0275580	-0.0275745	-0.0275660
-0.0275270	-0.0275575	-0.0275545	-0.0275450	-0.0275360	-0.0275210
-0.0275295	-0.0275390	-0.0275390	-0.0275325	-0.0274965	-0.0275115
-0.0275445	-0.0275365	-0.0275230	-0.0275365	-0.0275415	-0.0275375
-0.0275310	-0.0275665				

No. of Points= 50
Integ. Time= 2.00000000
Mean=-0.02759404
Std. Deviation= 0.00002406
Slope= 0.00000384
Y Intercept=-0.02769185

14:04:23 04/18/84

-0.0275810	-0.0275540	-0.0275465	-0.0275230	-0.0275070	-0.0275305
-0.0275130	-0.0274780	-0.0274775	-0.0274865	-0.0274815	-0.0274710
-0.0274920	-0.0274850	-0.0274625	-0.0274700	-0.0274830	-0.0274905
-0.0275150	-0.0275495	-0.0275445	-0.0275660	-0.0275410	-0.0275485
-0.0275595	-0.0274965	-0.0274955	-0.0274875	-0.0275055	-0.0274895
-0.0274840	-0.0275015	-0.0275100	-0.0275250	-0.0274680	-0.0274555
-0.0274810	-0.0275005	-0.0275055	-0.0274785	-0.0274630	-0.0274630
-0.0274765	-0.0274760	-0.0274695	-0.0274580	-0.0274555	-0.0274340
-0.0274095	-0.0274005				

No. of Points= 50
Integ. Time= 2.00000000
Mean=-0.02749492
Std. Deviation= 0.00003091
Slope= 0.00000150
Y Intercept=-0.02753304

Avg std dev= 0.00003610
std dev \ T= 0.00005105

Table 4. Automatic Mode Output (Continued)

14:05:18 04/18/84

-0.0274530	-0.0274590	-0.0274640	-0.0274520	-0.0274280	-0.0274400
-0.0274540	-0.0274820	-0.0275000	-0.0274840	-0.0274950	-0.0275160
-0.0275150	-0.0275020	-0.0275200	-0.0275150	-0.0275190	-0.0274940
-0.0274880	-0.0275250	-0.0275490	-0.0275550	-0.0275530	-0.0275790
-0.0275800	-0.0275440	-0.0275290	-0.0274790	-0.0274900	-0.0275000
-0.0275200	-0.0275090	-0.0274950	-0.0274790	-0.0274930	-0.0275020
-0.0275060	-0.0275190	-0.0275300	-0.0275230	-0.0275360	-0.0275510
-0.0275450	-0.0275480	-0.0275490	-0.0275370	-0.0275360	-0.0275450
-0.0275460	-0.0275410				

No. of Points= 50
Integ. Time= 1.00000000
Mean=-0.02751146
Std. Deviation= 0.00002718
Slope=-0.00000154
Y Intercept=-0.02747222

14:06:12 04/18/84

-0.0275210	-0.0274870	-0.0274780	-0.0274990	-0.0275030	-0.0275050
-0.0275190	-0.0275320	-0.0275260	-0.0275340	-0.0275340	-0.0275550
-0.0275620	-0.0275430	-0.0275350	-0.0275530	-0.0275600	-0.0275520
-0.0275680	-0.0275850	-0.0275810	-0.0275500	-0.0275390	-0.0275240
-0.0275250	-0.0275500	-0.0275270	-0.0275470	-0.0275430	-0.0275630
-0.0275910	-0.0275960	-0.0275820	-0.0275760	-0.0275770	-0.0275750
-0.0275740	-0.0275640	-0.0275530	-0.0275260	-0.0275590	-0.0275880
-0.0275970	-0.0275770	-0.0275760	-0.0275580	-0.0275370	-0.0275450
-0.0275510	-0.0275420				

No. of Points= 50
Integ. Time= 1.00000000
Mean=-0.02754888
Std. Deviation= 0.00002237
Slope=-0.00000114
Y Intercept=-0.02751981

Table 4. Automatic Mode Output (Continued)

```
14:07:07 04/18/84
  -0.0275590  -0.0275550  -0.0275580  -0.0275690  -0.0276030  -0.0276100
  -0.0276040  -0.0276230  -0.0276040  -0.0276050  -0.0276090  -0.0275770
  -0.0275770  -0.0275780  -0.0275570  -0.0275290  -0.0275200  -0.0275380
  -0.0275520  -0.0275530  -0.0275660  -0.0275620  -0.0275820  -0.0275840
  -0.0275880  -0.0275870  -0.0275850  -0.0276010  -0.0275900  -0.0275830
  -0.0275550  -0.0275630  -0.0275400  -0.0275170  -0.0275130  -0.0275140
  -0.0275380  -0.0275460  -0.0275180  -0.0275240  -0.0275470  -0.0275720
  -0.0275980  -0.0276220  -0.0276540  -0.0276670  -0.0276330  -0.0276220
  -0.0276250  -0.0276090

    No. of Points= 50
      Integ. Time= 1.00000000
             Mean=-0.02757570
   Std. Deviation= 0.00003667
            Slope=-0.00000030
      Y Intercept=-0.02756801

      Avg std dev= 0.00002935
       std dev \ T= 0.00002935


14:08:52 04/18/84
  -0.0275745  -0.0275860  -0.0275935  -0.0275765  -0.0275550  -0.0274985
  -0.0275025  -0.0275390  -0.0275710  -0.0275700  -0.0275755  -0.0275945
  -0.0276145  -0.0275840  -0.0275950  -0.0275860  -0.0275715  -0.0275800
  -0.0275800  -0.0275460  -0.0275770  -0.0276015  -0.0276040  -0.0275810
  -0.0275720  -0.0275985  -0.0276100  -0.0275825  -0.0275670  -0.0275790
  -0.0275920  -0.0275705  -0.0275815  -0.0276005  -0.0276025  -0.0275815
  -0.0275815  -0.0276095  -0.0276030  -0.0275945  -0.0275760  -0.0275620
  -0.0275780  -0.0275735  -0.0275745  -0.0275615  -0.0275680  -0.0275665
  -0.0275790  -0.0275860

    No. of Points= 50
      Integ. Time= 2.00000000
             Mean=-0.02757816
   Std. Deviation= 0.00002184
            Slope=-0.00000034
      Y Intercept=-0.02756950
```

Table 4. Automatic Mode Output (Continued)

14:10:36 04/18/84

-0.0275715	-0.0276125	-0.0276510	-0.0276415	-0.0276370	-0.0276460
-0.0276250	-0.0276145	-0.0275795	-0.0275225	-0.0275260	-0.0274825
-0.0274520	-0.0274545	-0.0274370	-0.0274660	-0.0274800	-0.0274910
-0.0274755	-0.0274850	-0.0274750	-0.0275183	-0.0275450	-0.0275660
-0.0275885	-0.0275910	-0.0275940	-0.0275690	-0.0275315	-0.0275320
-0.0275485	-0.0275655	-0.0275825	-0.0275610	-0.0275870	-0.0275615
-0.0275670	-0.0275275	-0.0275460	-0.0275820	-0.0275810	-0.0275600
-0.0275550	-0.0275685	-0.0275730	-0.0275955	-0.0276140	-0.0276255
-0.0276305	-0.0276545				

No. of Points= 50
Integ. Time= 2.00000000
Mean=-0.02755904
Std. Deviation= 0.00005602
Slope=-0.00000062
Y Intercept=-0.02754323

14:12:21 04/18/84

-0.0276275	-0.0275875	-0.0276180	-0.0276250	-0.0276135	-0.0276160
-0.0275975	-0.0275870	-0.0275900	-0.0276170	-0.0276540	-0.0276600
-0.0276455	-0.0276545	-0.0276495	-0.0276310	-0.0275970	-0.0275945
-0.0275970	-0.0275915	-0.0276265	-0.0276165	-0.0276335	-0.0275905
-0.0275915	-0.0275650	-0.0275590	-0.0275830	-0.0275435	-0.0275500
-0.0275470	-0.0275610	-0.0275770	-0.0275565	-0.0275625	-0.0275700
-0.0275425	-0.0275590	-0.0275630	-0.0275425	-0.0275250	-0.0275445
-0.0275665	-0.0275405	-0.0275455	-0.0275470	-0.0275395	-0.0275735
-0.0275470	-0.0275210				

No. of Points= 50
Integ. Time= 2.00000000
Mean=-0.02758487
Std. Deviation= 0.00002284
Slope= 0.00000204
Y Intercept=-0.02763691

Avg std dev= 0.00003714
std dev \ T= 0.00005252
IDVM Ver 2.0 14:12:24 04/18/84

III. INSTRUCTIONS FOR USING DATA ACQUISITION AND REDUCTION PROGRAM

The instructions for using the data acquisition and reduction program are described herein.

I. Load Tape

Press "LOAD", enter tape file number, press "EXECUTE".

II. Run Program

Press "RUN".

III. Operation of Program

A. 122'4 code(Y)? (see Note 1)

Enter "Y" and press "CONTINUE" for 122'4 code

or

Enter "N" and press "CONTINUE" or just "CONTINUE" for 1248 code.

B. Auto Mode (Y)?

Enter "Y" and press "CONTINUE" for automatic mode (see Note 2).

Enter "N" and press "CONTINUE" or just "CONTINUE" for manual mode (see Note 3).

1. Auto Mode

a. Label

Enter the title for which this test is to be conducted (up to 80 character positions) and press "CONTINUE".

b. Number of samples?

Enter number of samples desired and press "CONTINUE".

c. Sample integration time: T[1]=? (see Note 4)

Enter first integration time and press "CONTINUE".

d. Sample integration time: T[2]=?

Enter second integration time and press "CONTINUE".

e. Repeat as desired for a maximum of 19 integration times. Pressing "CONTINUE" instead of entering another integration time moves the program to the next step.

f. Number of blocks of samples? (see Note 5)

Enter number of blocks of samples and press "CONTINUE".

g. Number of iterations? (see Note 6)

Enter number of iterations and press "CONTINUE".

h. Data points listed (N)?

Enter "N" and press "CONTINUE" (see Note 7)

or

Enter "Y" and press "CONTINUE" (see Note 8)

i. Once "CONTINUE" is pressed the computer begins to collect data, automatically prints the number of samples, returns to step 1.a. ("Label") and waits for the next test sequence (see Note 9).

2. Manual Mode

a. Label

Enter the title (up to 80 character positions), and press "CONTINUE".

b. Number of samples?

Enter number of samples and press "CONTINUE".

c. Sample integration time (sec)?

Enter integration time ($\geq$ 0.01 to $\leq$ 99.99 sec) and press "CONTINUE". Data are now acquired.

d. Plot/list/or next (P/L/N)?

Enter "P" and press "CONTINUE" for a plot of the data acquired in 2.c. vs. the number of the sample.

or

Enter "L" and press "CONTINUE" for a list of the data acquired in 2.c. (see Note 8)

or

Enter "N" and press "CONTINUE". This step returns to 2.a. for the next sample cycle

or

If no letters are used, the following information will be listed on 9825T calculator tape:

Number of points

Means

Standard deviation of means

Slope of best least squares fit straight line

Y-intercept of best least squares fit straight line

e. (See Note 8).

NOTES:

1. The 2401C with option M21 has a 1248 code. Otherwise the 2401C has a 122'4 code.

2. In the automatic mode a wide variety of data taking sequences can be specified.

3. The manual mode is used for listing and/or plotting one block of data.

4. A maximum of 19 different integration times can be selected between > 0.01 to < 99.99 sec.

5. The number of blocks indicates the number of times data are repeated for each integration time. For example if two blocks are selected for integration times of 1, 2, and 5 sec (integration times are selected in 1.c.), each of which has 50 samples (number of samples are selected in 1.b.). The computer will accumulate data as follows

   50 samples, 1 second integration time for each sample
   50 samples, 1 second integration time for each sample
   50 samples, 2 second integration time for each sample
   50 samples, 2 second integration time for each sample
   50 samples, 5 second integration time for each sample
   50 samples, 5 second integration time for each sample

   The total is six blocks of data, and each block is stored, processed, and outputted separately.

6. The number of iterations indicates the number of times the data sequence described in Note 5 is repeated. For example, if the three iterations were asked for the sequence described in Note 5 would be repeated 3 times for a total of 18 blocks of data. Each block would be stored, processed, and outputted separately.

7. The printer will list:

   Number of points

   Integration time

   Mean of data

   Standard deviation of the data about a linear least squares fit to the data

   Slope of the linear least squares fit

   Y intercept of the linear least squares fit

   The standard deviation is computed as

$$\sigma = \left\{\frac{1}{N-1} \sum_{i=1}^{N} \left[y_i - (mx_i + b)\right]^2\right\}^{1/2}$$

where

N = number of data points

x_i, y_i = data set

m = slope of the linear least squares fit

b = Y intercept of the linear least squares fit

In Appendix C is discussed the effect of the time-bandwidth product of the input voltage on the calculation of σ.

8. The printer will list each measured integrated voltage (i.e., each mean) and also the information listed in Note 7 above.

9. At this time or any other time if one desires to get into the manual mode or from a manual mode into an auto mode or simply to get back to the beginning of the program because of an error, press "STOP" and press "RUN". The computer will advance to the beginning of the program which is step III.A., which asks the question "122'4 code (Y)?".

IV. 2401C INTEGRATING DIGITAL VOLTMETER CONTROL SETTINGS AND CONNECTIONS TO THE INTERFACE BUS

I. Front Panel of 2401C

A. Range: Depending on the amplitude of the input voltage, select one of five positions: 0.1, 1.0, 10, 100, or 1000 V.

B. Function: Set to "VOLT" position.

C. Sample Period: Set to "EXT SEL" position.

D. Sample Rate: Setting not important.

E. Attenuation: Setting not important.

II. Back Panel of 2401C

A. STORE DURING COUNT/DISPLAY DURING COUNT: Either position.

B. INT/EXT: Either position.

C. Program control (J1 connector): A coax is connected from the "START" BNC fitting on the interface box to J1 with the center conductor going to J1-b and the shield to J1-a and J1-z. A special coax is furnished with the interface box to make these connections.

D. Counter reset: Connect a coax from counter reset to the "RESET" input on the interface box.

E. BCD output (J2 connector): Connect to the interface box "BCD in" with 50 pin ribbon cable supplied with the interface box.

F. FREQ input: No connection.

G. 100 KHz STD, INPUT/OUTPUT: No connection.

H. 100 KHz STD, INT/EXT: Either position.

III. Interface Box to Calculator

A. Connect HP-IB from calculator to the interface box GPIB input.

APPENDIX A

REJECTION OF 60 Hz AND HARMONICALLY RELATED COMPONENTS

The addition of unwanted 60 Hz (i.e., pickup voltages) and harmonically related components to the wanted signal is a common laboratory problem. Depending on the integration time chosen the 2401C will provide a varying degree of rejection to the unwanted signal. Given an input unwanted voltage of amplitude V_u at frequency f_u, we can define a measure of rejection R as

$$R = \frac{\sigma_i}{\sigma_o(T)} \qquad \text{(A-1)}$$

where

σ_i = standard deviation of the unwanted voltage = $V_u/\sqrt{2}$

$\sigma_o(T)$ = standard deviation of the output mean voltage for an integration time of T and caused by the unwanted voltage

The output mean voltage $V_o(T)$ for an integration time of T and caused by the unwanted voltage is given by

$$V_o(T) = \frac{V_u}{\Delta\theta} \int_{\theta}^{\theta+\Delta\theta} \sin 2\pi f_u t \; d(2\pi f_u t) = \frac{V_u}{\Delta\theta} [\cos \theta - \cos(\theta + \Delta\theta)] \qquad \text{(A-2)}$$

where $\Delta\theta = \left(T/\frac{1}{fu}\right) \times 2\pi$ radians

The variance of $V_o(T)$ is, by definition,

$$\text{Var } V_o(T) = E[V_o - E(V_o)]^2 \qquad \text{(A-3)}$$

where E[ ] denotes mathematical expectation. Substituting (A-2) into (A-3), and noting that $E(V_o) = 0$ we have

$$\text{Var } V_o(T) = \left(\frac{V_u}{\Delta\theta}\right)^2 E\,[\cos^2\theta + \cos^2(\theta + \Delta\theta) - 2\cos\theta\cos(\theta + \Delta\theta)]$$

$$= \left(\frac{V_u}{\Delta\theta}\right)^2 \left\{\frac{1}{2} + \frac{1}{2} - 2E[\cos\theta\cos(\theta + \Delta\theta)]\right\}$$

$$= \left(\frac{V_u}{\Delta\theta}\right)^2 \left[1 - 2 \times \frac{1}{2\pi} \int_o^{2\pi} (\cos^2\theta \cos \Delta\theta - \cos \theta \sin \theta \sin \Delta\theta) d\theta\right]$$

$$= \left(\frac{V_u}{\Delta\theta}\right)^2 (1 - \cos \Delta\theta) \qquad \text{(A-4)}$$

From which we get

$$\sigma_o(T) = [\mathrm{Var}\ V_o(T)]^{1/2} = V_u \frac{(1 - \cos \Delta\theta)^{1/2}}{\Delta\theta} \qquad \text{(A-5)}$$

and finally

$$R = \frac{\sigma_i}{\sigma_o(T)} = \frac{\Delta\theta}{\sqrt{2}(1 - \cos \Delta\theta)^{1/2}} \qquad \text{(A-6)}$$

A plot of R vs. $\Delta\theta$ is given in Fig. A-1. Equation (A-6) was checked experimentally by putting a known 60 Hz voltage into the 2401C and then varying the sampling time. In Table A-1 are shown the results for a constant input of 10.3 mV rms for integration times of 10 through 190 ms every 10 ms. For each integration time 100 samples were taken, e.g., for an integration time of 40 ms, this means we would take 100 averages and each would be 40 ms long. As can be seen from the table the agreement between the calculated and experimental values of R are within about 5%, the experimental value being consistently higher, probably due to some systematic error, e.g., an error in the 10.3 mV rms measurement.

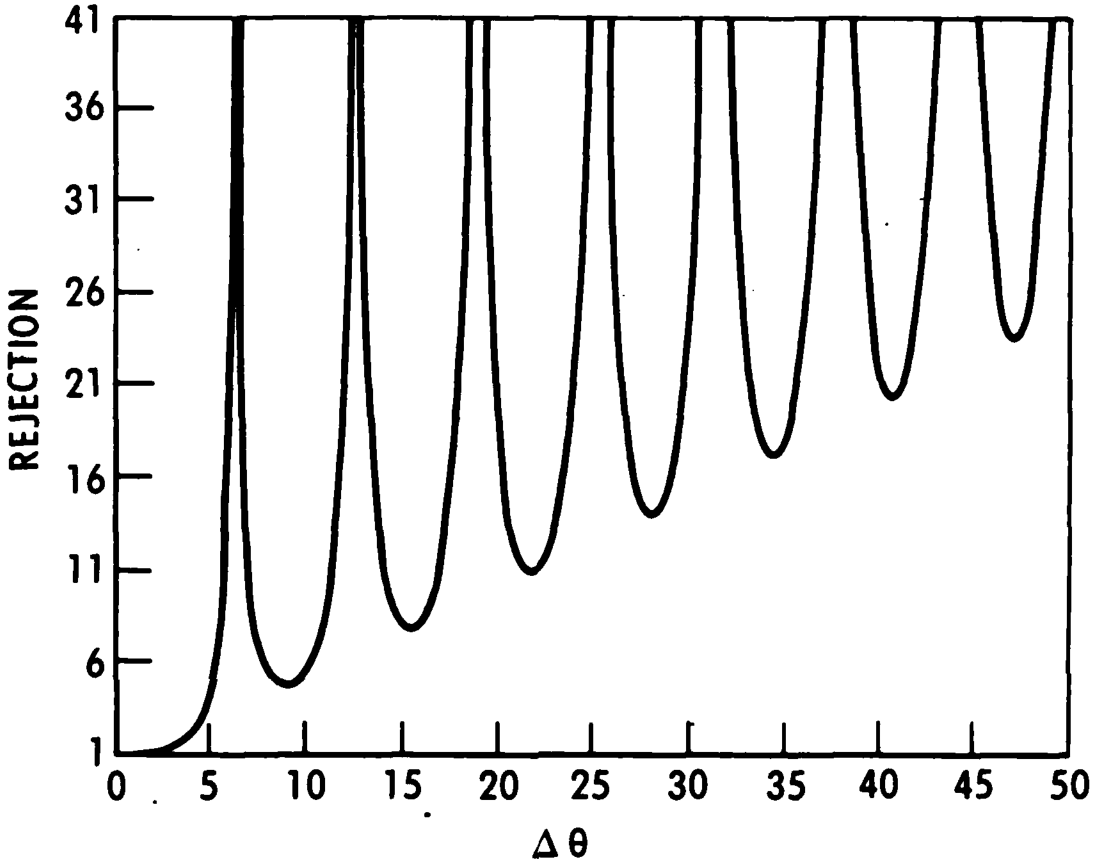


Fig. A-1. Rejection vs. Δθ

Table A-1. Experimental Determination of R as a Function of Integration Time (T)

T (ms)	R (predicted)	σ_o (mV rms)	$10.3/\sigma_o$
10	1.98	5.004	2.06
20	6.41	1.557	6.62
30	9.62	1.017	10.13
40	7.93	1.214	8.48
50	∞	0.0125	0.824×10^3
60	11.89	0.8081	12.75
70	22.45	0.4449	23.15
80	25.66	0.3881	26.54
90	17.84	0.5615	18.34
100	∞	0.00301	3.42×10^3
110	21.80	0.4446	23.17
120	38.48	0.2592	39.74
130	41.69	0.2363	43.59
140	27.75	0.3544	29.06
150	∞	0.00263	3.92×10^3
160	31.71	0.3114	33.08
170	54.52	0.1831	56.25
180	57.72	0.1706	60.38
190	37.66	0.2645	38.94

APPENDIX B

QUANTIZATION LEVEL OF THE 2401C

The 2401C consists of a very precise voltage to frequency converter (VFC) and a counter with a six digit display. The highest frequency out of the VFC is 310 kHz. In general, the number of counts, C, displayed on the counter is given by

$$C = \frac{10^5 V_i}{S} \times T$$

where

V_i = input voltage

S = voltage scale setting, choice of 0.1, 1, 10, 100, or 1000 V

T = counting time, choice of 0.01, 0.1, or 1.0 sec or can be externally controlled

Since the maximum frequency out of the VFC is 310 kHz, this means that the maximum allowed value of V_i is $3.1 \times S$. Values above that level will result in an overload indication. The maximum quantization level if the internal time base is used is then 1 part in 310,000 for a 1 sec count, 1 part in 31,000 for a 0.1 sec count, and 1 part in 3100 for a 0.01 sec count. If the count time is controlled externally, the maximum quantization is 1 part in 999,999. This of course requires that T be at least 1/0.31 = 3.2258 sec.

APPENDIX C

EFFECT ON THE CALCULATION OF σ OF THE TIME-BANDWIDTH PRODUCT OF THE INPUT VOLTAGE

For an ideal low-pass input bandwidth of B Hz and for an integration time of T, the error in σ has been shown[1] to be about 5, 2.5, and 1% for BT = 1, 2, and 4, respectively. To eliminate problems with overload of the 2401C caused by large high-frequency inputs, e.g., as might be caused by sharp spike pickup, we commonly low pass the input to the 2401C. Therefore, in order to make accurate calculations of σ, we choose the low-pass bandwidth B such that $BT \gg 1$.

[1] W. A. Johnson, "The Effects of a Finite Time-Bandwidth Product on the Variance of the Sample Mean of a Low-Pass Stationary Random Process," IEEE Transactions on Information Theory, Vol. IT-19, No. 1, January 1973, pp. 115-117. See Figure 2.

LABORATORY OPERATIONS

The Laboratory Operations of The Aerospace Corporation is conducting experimental and theoretical investigations necessary for the evaluation and application of scientific advances to new military space systems. Versatility and flexibility have been developed to a high degree by the laboratory personnel in dealing with the many problems encountered in the nation's rapidly developing space systems. Expertise in the latest scientific developments is vital to the accomplishment of tasks related to these problems. The laboratories that contribute to this research are:

Aerophysics Laboratory: Launch vehicle and reentry fluid mechanics, heat transfer and flight dynamics; chemical and electric propulsion, propellant chemistry, environmental hazards, trace detection; spacecraft structural mechanics, contamination, thermal and structural control; high temperature thermomechanics, gas kinetics and radiation; cw and pulsed laser development including chemical kinetics, spectroscopy, optical resonators, beam control, atmospheric propagation, laser effects and countermeasures.

Chemistry and Physics Laboratory: Atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiation transport in rocket plumes, applied laser spectroscopy, laser chemistry, laser optoelectronics, solar cell physics, battery electrochemistry, space vacuum and radiation effects on materials, lubrication and surface phenomena, thermionic emission, photosensitive materials and detectors, atomic frequency standards, and environmental chemistry.

Computer Science Laboratory: Program verification, program translation, performance-sensitive system design, distributed architectures for spaceborne computers, fault-tolerant computer systems, artificial intelligence and microelectronics applications.

Electronics Research Laboratory: Microelectronics, GaAs low noise and power devices, semiconductor lasers, electromagnetic and optical propagation phenomena, quantum electronics, laser communications, lidar, and electro-optics; communication sciences, applied electronics, semiconductor crystal and device physics, radiometric imaging; millimeter wave, microwave technology, and RF systems research.

Materials Sciences Laboratory: Development of new materials: metal matrix composites, polymers, and new forms of carbon; nondestructive evaluation, component failure analysis and reliability; fracture mechanics and stress corrosion; analysis and evaluation of materials at cryogenic and elevated temperatures as well as in space and enemy-induced environments.

Space Sciences Laboratory: Magnetospheric, auroral and cosmic ray physics, wave-particle interactions, magnetospheric plasma waves; atmospheric and ionospheric physics, density and composition of the upper atmosphere, remote sensing using atmospheric radiation; solar physics, infrared astronomy, infrared signature analysis; effects of solar activity, magnetic storms and nuclear explosions on the earth's atmosphere, ionosphere and magnetosphere; effects of electromagnetic and particulate radiations on space systems; space instrumentation.

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